2.6 Distance-Time Graphs

Radar antennas on ships send out pulses of radio waves. By measuring the pulses that reflect back from objects, such as other ships, a radar system can determine the location of the objects. Sonic rangefinders work in a similar way. These devices send out pulses of sound waves. By measuring the time it takes a pulse to reflect back from an object, the rangefinder can calculate the distance to the object.

Investigate A

How can you make distance-time graphs with a rangefinder?

Tools

- TI-83 Plus or TI-84 graphing calculator
- CBR™ (**c**alculator-**b**ased **r**angefinder)
- link cable

Work with a partner. There are several different models of rangefinders. Your teacher will tell you if the model you have requires any changes to the directions below.

1. Connect the CBR™ to a graphing calculator.

2. Set the calculator to record data from the CBR™:
   - Press APPS, select **CBL/CBR**, and press ENTER.
   - Select **3:RANGER**, press ENTER, and select **1:SETUP/SAMPLE**.
   - Make sure that your settings match those shown here. With these settings, the rangefinder will record distances in metres for a period of 4 s.
   - Move the cursor up to **START NOW** at the top of the screen, and press ENTER.

```
MAIN MENU   ▶START NOW
REALTIME:   NO
 TIME(S):   4
 DISPLAY:   DIST
BEGIN ON:   [ENTER]
SMOOTHING:  NONE
   UNITS:   METERS
```

3. Stand about 3 m from a wall, and hold the rangefinder with its sensor pointed at the wall. Press ENTER and walk slowly toward the wall for about 2 s. Pause for a moment; then, back away from the wall, slowly at first, but steadily faster for the remaining 2 s. Keep the sensor pointed at the wall as you walk. You will hear a clicking sound from the CBR™ as it measures distances.

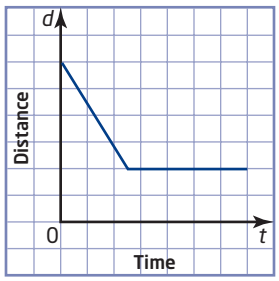
4. When the measurements are complete, a **distance-time graph** will appear on the calculator's screen. If you are not satisfied with your graph, press ENTER, and select **5:REPEAT SAMPLE**. Then, repeat step 3.

5. What does the horizontal axis of the graph represent? What does the vertical axis represent? Which variable is independent? Explain.

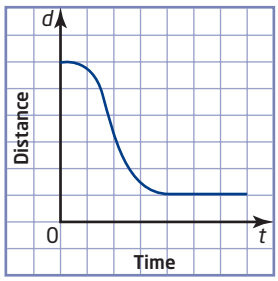
6. **a)** Describe the graph of your motion toward the wall.
   b) Describe the graph of your motion away from the wall.
   c) Describe the graph when you are standing still.
   d) Which parts of your graph are straight? Which part is curved? How does the motion represented by a straight part of your graph differ from the motion represented by the curved part?

7. Match each of the following distance-time graphs by pointing the CBR™ at a wall and walking toward or away from the wall. Describe how you moved to match each graph.

a)



b)



8. **Reflect** Summarize how different kinds of motion appear on a distance-time graph.

distance-time graph

- a graph that shows how distance varies with time

Investigate B

How can you graph the motion of a falling object?

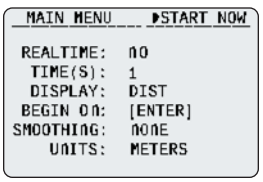
Work with a partner to produce a distance-time graph for a falling ball.

Tools

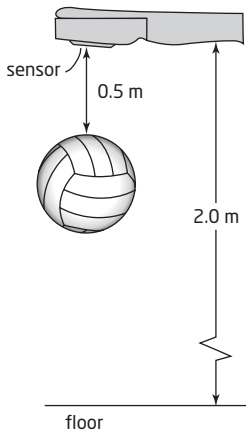
- TI-83 Plus or TI-84 graphing calculator
- CBR™ (calculator-based rangefinder)
- link cable
- large ball (such as a basketball or volleyball)

1. Connect the CBR™ to a graphing calculator.

2. Set the calculator to record data from the CBR™:
   - Press APPS, select **CBL/CBR**, and press ENTER.
   - Select **3:RANGER**, press ENTER, and select **1:SETUP/SAMPLE**.
   - Make sure that your settings match those shown here. With these settings, the rangefinder will record distances in metres for a period of 1 s.
   - Move the cursor up to **START NOW** at the top of the screen, and press ENTER.



3. One partner holds the CBR™ steady about 2.0 m above the floor and points the sensor downward. The other partner holds the ball 0.5 m directly below the CBR™. Press ENTER and immediately release the ball. Let the ball bounce.

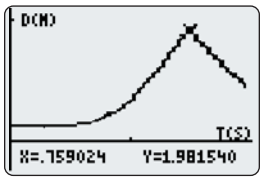


4. When the measurements are complete, a distance-time graph will appear on the calculator's screen. If you are not satisfied with your graph, press ENTER, and select **5:REPEAT SAMPLE**. Then, repeat step 3.

5. What does the horizontal axis of the graph represent? What does the vertical axis represent?

6. How you can identify the point on the graph where the ball hit the floor?

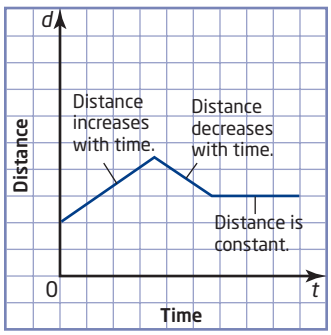
7. Use the **TRACE** feature to find the coordinates of this point. Press TRACE, and use the arrow keys to move the cursor along the graph to the point where the ball hit the floor. What do the coordinates of this point represent?



8. **Reflect** Is the relation between distance and time linear from the time you released the ball until it reached the floor? Explain how you can tell from the distance-time graph. What can you conclude about the speed of the ball?

Key Concepts

- A distance-time graph shows an object's distance from a fixed point over a period of time.
- On these graphs, a rising line shows that the distance increases as time increases. A falling line shows a decrease with time, and a horizontal line shows that the distance remains constant.



Communicate Your Understanding

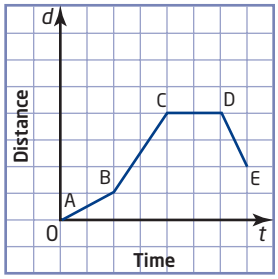
C1 State which phrase best describes each segment of this distance-time graph. Justify your answer.

a) no movement

b) fastest movement

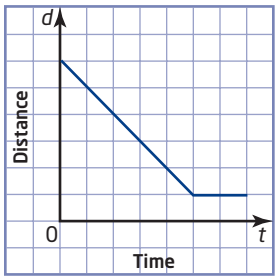
c) slowest movement

d) backward movement

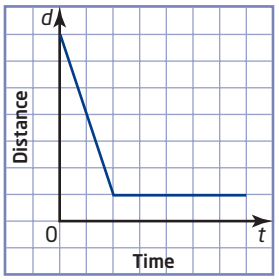


C2 These graphs show a person's distance from a wall. Describe the motion shown in the first graph. Then, explain how the motion in each of the other two graphs differs from that shown in the first graph.

a)



b)



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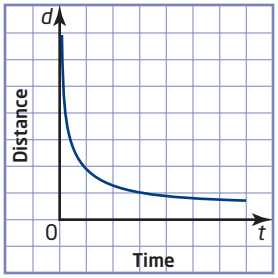
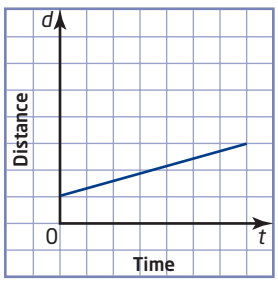


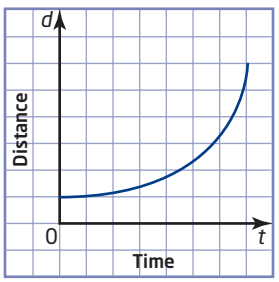
Practise

1. Describe the motion shown in each distance-time graph. Write a few sentences describing a situation that could be represented by each graph.

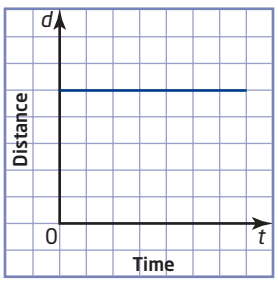
a)



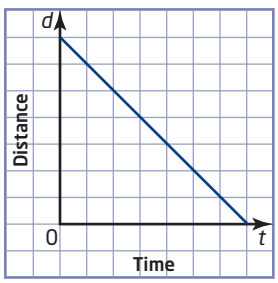
b)



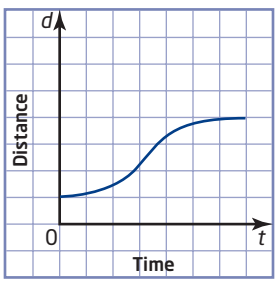
c)



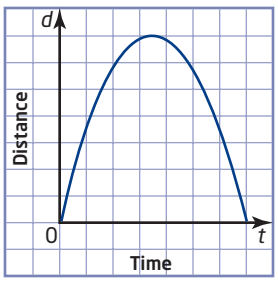
d)



e)



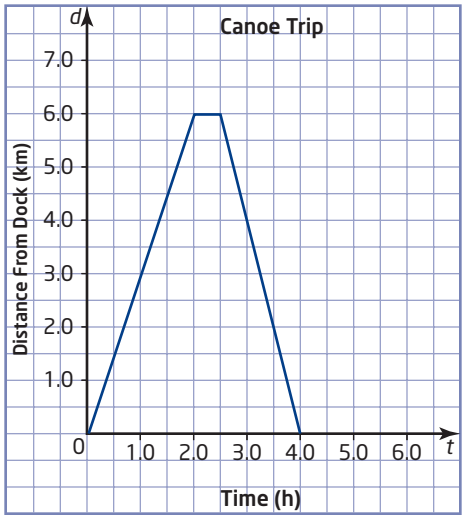
f)



2. Which of the graphs in question 1 show linear relations between distance and time? Justify your answer.

Connect and Apply

3. A canoeist starts from a dock and paddles to the end of a lake and back. This graph shows the canoeist's distance from the dock during this trip.



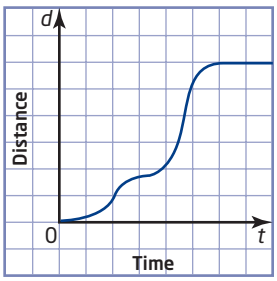
a) How long did this trip take?

b) How far is it to the end of the lake?

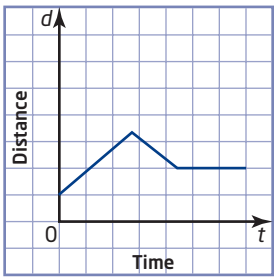
c) What does the flat portion of the graph represent?

d) Was the canoeist travelling faster on the way out or on the way back?

4. This graph shows how far a cyclist has travelled from her starting point. Describe the cyclist's motion in a few sentences.



5. a) You are holding a rangefinder pointed at a nearby wall. Describe how you would move in order to match this graph.



b) How would the distance-time graph change if you walked faster?

c) How would the graph change if you walked slower?

d) How would the graph change if you stopped sooner?

e) If a rangefinder and graphing calculator are available, use them to check your answers to parts b), c), and d).

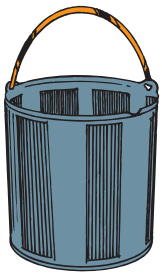
6. **a)** Sketch your own distance-time graph.
   b) Describe the motion shown in your graph.
   c) If a rangefinder and graphing calculator are available, use them to check your answer to part b).

7. Draw a distance-time graph for this situation:
   A student leaves home, walking at a steady pace. He slows down, then stops for a few seconds to mail a letter. He turns around and runs home at a constant speed.

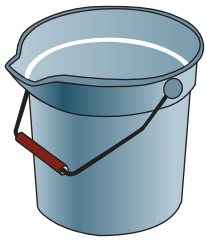
8. Sketch a distance-time graph for a car that slowly speeds up after stopping at a traffic light.

9. Water is flowing at a constant rate into each pail. The pails have the same height and the same base. Draw a graph showing the depth of the water in each pail during the time it takes to fill the pails.

a)



b)



10. **Use Technology** Carry out this activity with a small group.
    a) Connect a CBR™ to a graphing calculator.
    b) Press APPS, select **CBL/CBR**, and press ENTER. Then, select **3:RANGER**, press ENTER, and select **3:APPLICATIONS**. Select **1:METERS** and then **1:DIST MATCH**.
    c) Follow the instructions on the screen. Have each member of the group try to match a different distance-time graph.
    d) Write a brief summary of what you learned about distance-time graphs.

Technology Tip

CLR/CBR may appear anywhere on the **APPLICATIONS** menu. If **CBL/CBR** is not among the first seven items, scroll down to see the rest of the list.

Extend

11. **a)** Find the speed of the canoeist in question 3 during each of the three segments of the trip.
    b) Draw a speed-time graph for the canoeist's trip.
    c) How is the speed of the canoeist related to the shape of the distance-time graph?
    d) What does negative speed represent in this situation?

12. Use Technology Work with a partner to investigate the motion of a bouncing ball. Use a large ball, such as a basketball or a volleyball.

a) Connect a CBR™ to a graphing calculator. Clear all lists.

b) Press APPS, select **CBL/CBR**, and press ENTER. Then, select **3:RANGER**, press ENTER, and select **3:APPLICATIONS**. Select **METERS** and then **BALL BOUNCE**.

c) Follow the instructions on the screen. Hold the CBR™ up high with the sensor pointed down. Drop the ball from a point about 0.5 m directly below the CBR™. Press the trigger on the CBR™ the moment the ball first hits the floor. Allow the ball to bounce at least five times.

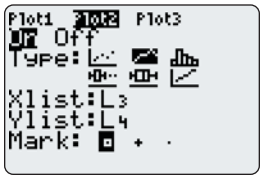
d) When the measurements are complete, a graph will appear on the calculator's screen. What does the horizontal axis of this graph represent? What does the vertical axis represent?

e) Is there a linear relation between these two variables? Explain.

f) Use the **TRACE** function to find the maximum height the ball reaches on each bounce. Move the cursor to the top of the curve representing each bounce. Record the coordinates of these points in a table under the headings "Time" and "Bounce Height."

g) Enter the times into list **L3** and the bounce heights into **L4**.

h) To plot these coordinates, Press 2nd **[**STAT PLOT**]** and select **2:Plot2**. Select **On** and the line graph icon. Enter L3 for **Xlist** and L4 for **Ylist**. Then, press GRAPH.



i) Is there a linear relation between time and bounce height? Explain.

13. Use Technology Carry out this activity with a small group.

a) Connect a CBR™ to a graphing calculator.

b) Press APPS, select **CBL/CBR**, and press ENTER. Then, select **3:RANGER**, press ENTER, and select **3:APPLICATIONS**. Select **1:METERS** and then **2:VEL MATCH**.

c) Follow the instructions on the screen. Have each member of the group try to match a different speed-time graph.

d) Write a brief summary of what you learned about speed-time graphs.

14. Math Contest In 2005, Shaheen's age on her birthday was equal to the sum of the digits of the year she was born. In what year was Shaheen born?